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by

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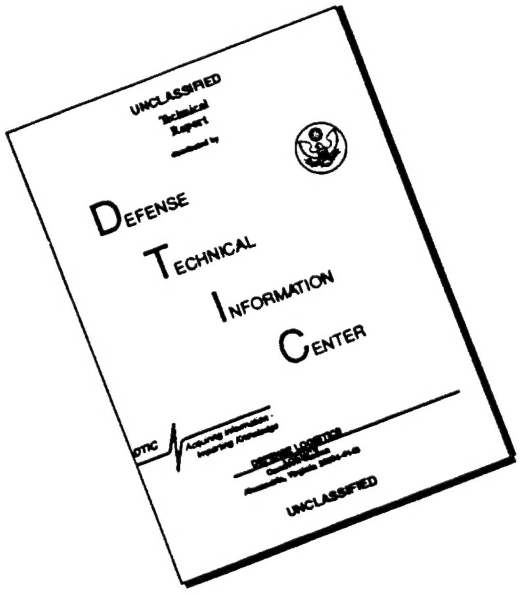

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RESEARCH ON HUMAN SKIN INJURY THRESHOLDS FOR PULSED CARBON DIOXIDE LASERS

Chen Ji, Shi Liangshun, Qian Huanwen, Li Enjiang, Zhang Jianjun

ABSTRACT

These experiments made use of pulsed carbon dioxide lasers to irradiate the flexor side skin of people's forearms. Observations were made of the occurrence rate of cutaneous erythema and the appearance times for erythema. Cutaneous erythema occurrence rates and irradiation doses present linear relationships. When doses are large, cutaneous erythema occurrence rates are high. When irradiation doses are low, erythema occurrence rates are low. MRD50 irradiation dosage was obtained as approximately 0.4J/cm2.

Laser technology has been applied widely in military matters--for example, laser range finding, weapons simulation in military training, laser indicators, as well as laser communications, and so on. Among these, applications of CO2 lasers are growing more numerous by the day. Starting out from the angle of laser safety protection, reports researching CO2 laser damage threshold values with regard to eyes and skin are mostly related to continuous transmission CO2 laser materials [1-3]. However, research on pulsed CO2 laser damage threshold values with respect to skin has still not been seen. In order to draw up Chinese military laser safety protective standards, it is necessary to supply physiological data associated with pulsed CO2 laser damage threshold values with regard to the skin of Chinese people. To this end, experiments were designed.

EXPERIMENTAL METHODS AND EXPERIMENTAL SUBJECTS

Experimental instruments: vacuum electrical discharge pulsed type transmission CO2 laser device developed by the Chinese Academy of Sciences Physics Research Institute; cavity length 1.05m; diameter 50cm; output wave length 10.6μm; pulse width is ~ 180ns; degree of output instability is ±5%; maximum output energy 760mJ; however, the experiments used 350mJ.

Dose measurements: pulsed CO2 laser beams pass through germanium lens focusing (focal length approximately 14cm). They then pass through a diaphragm aperture with a diameter of 5mm and enter into a JNK-1 model laser energy meter. The latter is displayed by an AC15/5 model galvanometer. Test measurements are done of the output energies before irradiation of human skin and after irradiation in order to facilitate the achievement of the required irradiation doses.

Personnel participating in the experiments: the people participating in the experiments in question were all male scientific and technical personnel from this laboratory. There were a total of 13 (illegible) people. All of them were ethnic Han Chinese. Their average age was 42.5±8.9 years. Due to the limitations of laboratory conditions, they were all irradiated on their right forearm skin. Before laser irradiation, forearm flexor skin was washed clean and very lightly rubbed dry. In conjunction with this, it was coated once with physiological saline. After the water dried, laser irradiation was carried out. Before irradiation, a square grid was drawn out on the forearm flexor skin. The first irradiation spot was at a place

3cm below the central lateral furrow associated with the hollow of the elbow. Using a 2cm distance for each interval the next pattern point was irradiated. In two grid arrangements, there were a total of 16-18 pattern points. Each pattern point on the forearm flexor skin was irradiated with different laser doses, causing skins with different reflectances to be distributed within nine dose sets. Each set is 10-16 pattern points different in order to facilitate finding 50% minimum redness doses (MRD50) associated with groups.

Observation methods: after laser irradiation, macro inspection was carried out immediately of skin reactions in areas subject to irradiation and of erythema appearance times. At fixed later times, follow up visit inspections were done. Besides recording erythema appearance times, the forms which erythema presented were also recorded. Generally, observations were done by two people in all cases--for accuracy--and, in conjunction with that, photographic records were made.

EXPERIMENTAL RESULTS

The experiments in question irradiated a total of 198 pattern points. Among these, there were 190 effective pattern points, distributed in nine dose groups. Each group was approximately 10-26 irradiation pattern points (Table 1). From Table 1, it is possible to see that, when human forearm flexor skin is irradiated by CO2 laser light, erythema production rates are different due to irradiation doses. As far as large irradiation doses are concerned, skin erythema production rates are high. By contrast, due to irradiation doses also being low, skin erythema production rates are also low. For example, dose groups 1-3 are, respectively, comparatively high irradiation doses. Skin erythema production rates are 100% in all cases. However, irradiation doses associated with dose group No.9 were the lowest. Among 26 skin irradiation pattern points, there was only the appearance of 1 erythema. Moreover, it was very weak--only accounting for 3.8%.

Because of irradiation doses, skin erythema appearance times are different. When irradiation doses are large, skin erythema in areas subject to irradiation appears rapidly. Occurrence rates are also high. When irradiation doses are low, skin erythema occurrence rates are low. Appearance times are delayed. For example, dose groups 1-3 have skin erythema occurrence rates in areas subject to radiation which are 100% in all cases. The appearance times are also comparatively fast and early. Among these, there are 4 people whose skin erythema appears immediately after laser irradiation. Besides these, there are 9 people whose

cutaneous erythema does not appear until within 1-70 minutes after laser irradiation. Most of the cutaneous erythema associated with dose groups 4-8 do not appear until one half hour to 1 h after laser irradiation. Moreover, dose group 9 only showed the appearance of a weak cutaneous erythema 10 hours after laser irradiation (Table 2). The explanation of this is that, because irradiation doses fall, appearance times associated with cutaneous erythema within a 24 hour observation period get pushed back little by little.

Areas of skin subject to irradiation formed small, circular erythema. However, they certainly were not swollen--only presenting localized redness (Fig.1). After a period of time, some people had a slightly itchy feeling in association with cutaneous erythema. 48 h after irradiation, the itchy feeling basically disappeared. Cutaneous redness also showed dark red colors or turned weak and disappeared. /41

MRD50 calculations: under the conditions of the experiments in question, cutaneous erythema occurrence rates associated with dose groups 1-3 were 100% in all cases. As a result, during

Table 1 Pulsed CO2 Laser Irradiation Amounts Against Human Forearm Flexor Skin and Erythema Occurrence Rates

(1) 组别	平均照射剂量±5x (mJ) (2)	照射能量密度 (mJ/cm²) (3)	样点数 (个) (4)	红斑发生数 (个) (5)	红斑发生率 (%) (6)
1	148.4±5.9	757.1	26	26	100
2	133.8±4.2	682.7	26	26	100
3	125.6±1.1	640.8	10	10	100
4	114.6±3.6	584.7	26	25	96.2
5	104.0±2.3	531.6	16	14	87.5
6	84.2±1.7	429.6	26	17	65.4
7	69.8±2.2	356.1	16	4	25.0
8	53.4±0.7	272.4	26	3	11.5
9	31.4±2.4	160.2	26	1	3.8

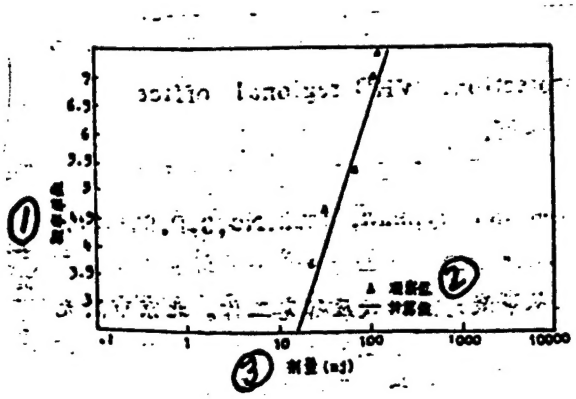
Key: (1) Group (2) Average Irradiation Dose ±5x (mJ) (3) Irradiation Energy Density (4) Lattice Point Number (5) Erythema Occurrence Number (6) Erythema Occurrence Rate (7) Per

Table 2 Distribution of Erythema Occurrence Rates Associated with Different Times after Laser Irradiation

① 组别	照射剂量 (mJ) ②	红斑数 (个) ③	照后即刻 ④	1～60min	1～5h	5～24h
1	148.4	26	8(30.8%)	16(61.5%)	2(7.7%)	—
2	133.8	26	8(30.8%)	18(69.2%)	—	—
3	125.6	10	2(20.0%)	8(80.0%)	—	—
4	114.6	25	—	23(92.0%)	2(8.0%)	—
5	104.2	14	—	10(71.4%)	4(28.6%)	—
6	84.2	17	—	9(52.9%)	8(47.1%)	—
7	69.8	4	—	1(25.0%)	3(75.0%)	—
8	53.4	3	—	—	2(66.7%)	1(33.3%)
9	31.4	1	—	—	—	1(100%)

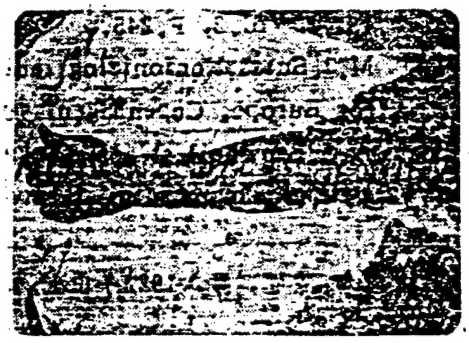
Key: (1) Group (2) Irradiation Dose (3) Erythema Number (Per) (4) Immediately After Irradiation

Table 1 Damage Threshold Probability Analysis Curve for Pulsed CO2 Laser Irradiated Human Skin



Key: (1) Probability Units (illegible) (2) Observed Values Calculated Values (illegible) (3) Dose

Table 2 Erythema Appearing on Human Forearm Skin After Laser Irradiation



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statistical processing, groups 1-2 were dropped. The other seven dose groups were 125.6 - 31.4 mJ (Fig.2). The various (illegible) laser irradiation doses and their corresponding cutaneous erythema occurrence rates are taken through probability processing associated with second order iterative weighted probability unit analysis. As the far as MRD (illegible) 73.97mJ is concerned, the 95% reliability limit range is 0.34282-0.41024mJ/cm2.

DISCUSSION

CO2 laser radiation wave length is 10.6μm. It is very easily absorbed in water. Moreover, for water, dulling lengths with regard to CO2 laser light are (illegible) short--only around 0.3mm [4]. The absorption coefficient α is very large, being approximately 950cm-1. Skin is an organ (illegible) of the human body which contains a very large water component. The water content is approximately 62-71%. The 50% near infrared ray skin penetration depth is approximately 0.8mm[5]. As a result, CO2 (illegible) light irradiation on skin is primarily, first, evaporation of water content. After that, it creates local skin temperature rises--that is, the CO2 laser energy transmitted in is greater (illegible) than the heat dissipating capabilities of local tissues. Local skin is heated, making capillaries expand. As a result, one has the appearance of red colored spots--that is, cutaneous erythema. However, the influences of skin pigmentation contents on energies absorbed at 10.6μm are very small.

It is normally believed that laser damage to the skin is not as important as damage to the eyes. However, skin damage threshold values are capable of being comparable to eye cornea (illegible). With the exception of damage associated with lasers in the visible spectral region and near infrared spectral region (400-1400nm) on retinas, skin (illegible) thresholds are, in general terms, very close to corneal damage thresholds [6]. However, the possibilities of skin being subject to laser irradiation are still greater than for corneas. During pulsed CO2 laser (illegible) irradiation of rabbit corneas, the MRD50 is 200mJ/cm2 [7]. This is very close to the experimental values obtained under the conditions of the tests in question (pulse width [illegible] approximately 180ns, MRD50 approximately 389.3mJ/cm2).

CONCLUSIONS

These experiments made use of CO2 lasers to irradiate human forearm flexor skin. Observations were made of cutaneous erythema occurrence rates as well as erythema appearance times and the forms which were taken. Cutaneous erythema occurrence

rates and irradiation doses present linear relationships. When irradiation doses are large, erythema occurrence rates are high. When laser irradiation doses are (illegible), erythema occurrence rates are low. The pulsed CO2 laser irradiation dose which achieves a 50% cutaneous erythema occurrence rate--that is, MRD50 is approximately equal to 389.3mJ/cm2 (band width is ▪180ns). Each square centimeter is 389.3 mJ.

* * *

Brief introduction of the authors: Chen Ji is male. Born 1927. Assistant research fellow. Engaged in research work associated with laser biological effects. Member of Beijing Municipal Committee on the Use of Lasers in Medicine. Qian Huanwen is male. Born November 1950. Engineer. Engaged in research associated with laser devices. Draft date: 3 October 1987.

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